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ROUTING ALGORITHM FOR OPTIMIZING ENERGY CONSUMPTION IN WIRELESS SENSOR NETWORK FOR ENVIRONMENT MONITORING

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ABSTRACT

By considering the benefits of using Wireless Sensor Network in Environment Monitoring, an appropriate structure for Wireless Sensor Network based on clustered and hierarchical models will be proposed. By applying different policies in each layer of proposed structure, energy consumption will be decreased. Furthermore, by studying the characteristics of the Wireless Sensor Network for Environment Monitoring, a new proper routing algorithm for using in the proposed Wireless Sensor Network will be presented. The proposed algorithm is based on some wildly used routing algorithm that adapted for the proposed structure for environment monitoring. By applying the proposed routing algorithm in the proposed structure energy consumption will be decreased and the time limitation for real-time data will be guaranteed. Increasing data transfer reliability is another benefit of proposed structure. A WSN is a collection of autonomous devices organized into a cooperative radio network. Each node is connected to one or several sensors, and may monitor various physical or environmental conditions, such as temperature, vibration, motion, radiation activity. WSN can vary from a few to thousands nodes equipped with transceivers for low range wireless communication.

KEYWORDS: Environment Monitoring, Energy Consumption Optimization, Sensor Node, Routing Algorithm, Wireless Sensor Network

1. INTRODUCTION

As long as human lives on the earth, they are always being to face natural disasters such as flood, earthquake, tsunami, and etc. Every year there are millions of people tackle with loss of life and other financial and emotional determinants of these monitoring. Therefore this is to be one of the important challenges how to face these events. Over many years and despite dramatic advances in science and technology, human could not yet help prevent the occurrence of these natural hazards. So people must look for a solution to minimize damages caused by these events [1 and 2].

Environment monitoring can be considered as a solution to answer questions in any time and any place the disaster happens. Saving people’s life and reducing causalities and damages to a minimum in time of hazard consist of three phases: disaster preparedness, response and relief in times of disaster, and post-disaster repair [3].Over the technological advances, new structures have been presented for environment monitoring in various situations. One of these structures is Wireless Sensor Network (WSN). Low cost and no need for hardware infrastructures cause the popularity of these networks and applying them in different applications such as environment monitoring in order to timely detection of disaster and damage reduction. As one of the biggest problems in time of environment change is determinant of communicational infrastructures, WSN can be one of the most suitable infrastructures to be applied in environment monitoring because of their wireless and self-organized characteristics. Wireless Sensor Networks are made up of a set of sensor nodes coordinated for a specific task. Graph is the topology used in these networks which provides easy deployment of the nodes anywhere in the network without any particular limitation. The base of such networks is on sensor nodes

deployed in the area collecting information and sending them to a receiver to be sorted and processed. Battery is the resource providing sensors' energy. Sensors are often deployed in places the battery cannot be replaced, so their life time and consequently life time of the whole network totally depend on battery life. Therefore energy consumption should be mentioned to be one of the most important challenges in these networks.

Major issue in designing WSN is presenting an amorphous structure and a suitable routing algorithm which can increase the network lifetime. For this purpose, here a WSN has been proposed for environment monitoring. To increase the efficiency of proposed network in addition to increasing its lifetime via comparing routing algorithm, energy efficient routing algorithms is presented. Continuing in part 2, related work is studied and then in part 3, optimizing energy consumption in WSN and categorizing energy efficient routing algorithms are briefly addressed. Also suitable routing demands of a WSN are proposed for environment monitoring and after that in part four, the structure of a wireless network appropriate for environment monitoring is proposed and suitable routing algorithm for this structure will be proposed. In the fifth part the capability and challenges of proposed structure will be discussed, and at last, conclusions are presented.

2. RELATED WORK

Saha et al. in [4] presented a WSN protocol for disaster management (WSNPDM) that distributes energy over the network by its multi-hop routing technique along with a residual energy based clustering method in modified hybrid networks framework. They claimed that with this protocol average energy dissipation is lower.

XUAN et al.In [2] provided a model for effective disaster early warning monitoring and management system. To reach this point, systematic ideas are applied, weakness links in the current systems are pointed out and some suggestions for better disaster management provided.

Silva et al. In [1] presented an energy efficient mechanism for processing spatial queries on WSNs to detect dangers in disaster situations. The proposed mechanism manipulates queries with regions of interest that have irregular shapes and reduce the overhearing consumption. In the scenarios analyzed, this mechanism decreased by about 60% of energy consumption, with an inaccuracy of approximately 14% in information collected, if compared with the network without improvements.

Bahrepour et al. in [5] introduced machine learning techniques for distributed event detection in WSNs and evaluated their performance and applicability for early detection of disasters, specifically residential fires.

Pei Huang et al [16] Wireless Sensor Networks (WSNs) have become a leading solution in many important applications such as intrusion detection, target tracking, industrial automation, smart building and so on. Typically, a WSN consists of a large number of small, low-cost sensor nodes that are distributed in the target area for collecting data of interest. For a WSN to provide high throughput in an energy-efficient way, designing an efficient Medium Access Control (MAC) protocol is of paramount importance because the MAC layer coordinates nodes' access to the shared wireless Medium. Also they presented a distributed event detection approach incorporating a novel reputation-based voting and the decision tree and evaluated its performance in terms of detection accuracy and time complexity. They claim that their approach not only achieves a high detection rate but also has a low computational overhead and time complexity.

3. ENERGY EFFICIENCY

Saving energy in WSNs occur through different methods such as reducing sent and processing data (via methods like compression), algorithm overhead reduction, topology control, defining task periods (in each period, a fraction of sensors are active), and at last routing with optimal energy consumption helping network lifetime increases by means of

applying the most suitable routing algorithm according to the network application and mentioned requirements in that specific application [6].After that, first an important category of routing algorithms has been addressed in this network and then the appropriate routing requirements for disaster management will be studied.

Energy Efficiency Routing Algorithm

In design of routing algorithm for WSNs some issues such as limitation of sensors' energy supply, instability of the quality of transmission medium (radio channels), lack of fixed topology, probability of node damaging and etc. should be considered. Proposed routing algorithms in WSNs can be classified in the following general categories:

- **Data Centric Routing Algorithm**: in this category data is considered to be more significant. Thus queries are posed for specific data rather than for data from a particular sensor. SPIN (sensor Protocols for Information via Negotiation) [7] and DD (Directed Diffusion) [8] are the first algorithms proposed in this area [9].
- **Location-Based Routing Algorithm:** each node keeps some location information from their direct neighbors and transmits its request to the most appropriate neighbor. GAF [10] is one of the most important algorithms noted in this category [11].
- **Hierarchical Routing Algorithm:** clustering nodes reduces power consumption. LEACH [12] is one of the most widely used algorithms in this category [11].
- **Routing Algorithm Based on Quos Assurances:** these algorithms use different methods for routing optimization based on different Quos requirements reliability, bandwidth, and etc. [9].

Appropriate Routing Requirements for Environment Monitoring

As timely and quick action is critical in time of disaster, collecting environmental monitoring information in the shortest possible time seems to be necessary. For example, fire near gas lines or leaks of radioactive material from a nuclear powerhouse can quickly lead to a fatal disaster. Therefore this information should be transmitted in real-time. Although issues such as reporting the intensity of aftershocks after the earthquake it is not that much important if the information is not send in real-time or not (though it also have to support soft real-time), but reliability is highly important in sending such information. Thus for the purpose of disaster management, WSNs are encountered with a combination of real-time and non-real-time data. So the algorithm should be designed able to optimize routing both types of the data. This factor results in increasing the complexity of the routing algorithms.

Another important issue to be considered in design of routing algorithms for WSNs in environment monitoring is frequent increasing traffic in a part of the network and lack of traffic in another part of that, which makes some parts energy, depleted rapidly and leads to death of all sensors on Those regions and breakdown of the critical parts of the network. Thus the routing algorithm must be designed so that traffic distributed uniformly all over the network and also for equal consumption of sensors energy. Because in time of disaster (flood, earthquake, explosion, and etc.)Sensors might be exposed to destruction and loss of information, routing should be such that critical data receive in destination with high reliability (e.g., using techniques such as critical data replication, or sending data from multiple paths). Hence, it is necessary to use a routing algorithm saving energy along with considering real-time requirements and transport monitoring data with minimum rate of packet loss and high reliability.

Cluster-Trees

Cluster-Tree

A Tree is constructed, rooted at the PAN coordinator. All the non leaf-nodes are designated as *coordinators* since they may forward the traffic to or from the root.

Non-Beacon Mode

In a cluster-tree, we may authorize some nodes to be categorized as Reduced-Function Devices (RFD). These nodes cannot relay packets because of energy constraints. Since they would constitute leaf nodes in the cluster-tree, they may sleep safely. However, all other nodes are Full-Function Devices (FFD) and cannot sleep: energy savings are very limited.

Beacon-Enabled Mode

As highlighted previously, all the transmissions are initiated by the children, i.e. the coordinator cannot start a transmission before a solicitation of its child. This feature permits to implement efficient power-saving mechanisms. As *follower* (i.e. a node which participates to a super frame without coordinating it), a node must wake-up to receive at least one beacon every mac Transaction Persistence Time. If packets are pending, it must retrieve them immediately by transmitting a data-request. As soon as a follower has neither pending packet nor packet in its own buffer to transmit to its parent, it may sleep. As coordinator, a node must stay awake during the whole active part of its super frame. For all these reasons, the beacon-enabled mode should be privileged since this constitutes the only way to optimize the energy consumption in multichip topologies.

Active Discovery

A node enters in *active scan* and sends a beacon-request on each operational channel. An already associated coordinator MUST reply with a beacon if the PAN works in the *non-beacon* mode, otherwise the coordinator ignore the beacon-request and continue sending its periodic beacons. Upon reception of a beacon, the node can engage the association procedure. If many nodes begin an active scan simultaneously, we may face to collisions. Besides, this method must be carefully implemented in beacon-enabled mode: a coordinator may sleep during the passive part of the super frame. Thus, one beacon-request has to be transmitted every Super frame Duration (SD), each channel being scanned during Beacon Interval (BI).

Passive Discovery

In beacon-enabled mode, a coordinator MUST transmit every Beacon Interval (BI) its beacon at the beginning of the active part of its super frame. Thus, a node may implement a *passive scan*: it has to stay at least BI on a channel to receive any beacon from already associated coordinators. If BI and channel are not known a priori, the node may assume the worst case, leading to very long discovery times. This strategy is impossible in non-beacon mode since an associated coordinator does not send any periodical packet.

4. PROPOSED MODEL FOR WIRELESS SENSOR NETWORK

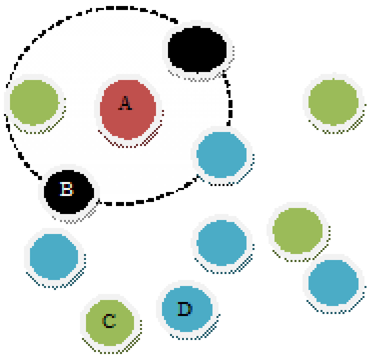
In this section a proposed model for WSNs with an energy efficient routing algorithm and suitable to be applied in environment monitoring is going to be introduced.

A. Structure of Proposed Network

In this section proposed structure, components of this structure, and properties of these components is described. In environment monitoring, nodes of the proposed sensor network have to proper for deployment in environment with particular climate (e.g., high humidity such as sea, high temperature such as fire, or etc.) and also against severe impacts (explosion). In case of accidents such as fire and explosion, they should have the ability of self-clearing and self- configuration. In proposed model, there are nodes with different resource and functionality like: Vibration sensor nodes to detect the occurrence of any environmental movement (earthquake, pre earthquake, aftershock, detecting victims under rubbles, and etc.).

- Temperature sensor nodes(C) to diagnose the occurrence of explosion and fire in the area.
- Acoustic sensor nodes to detect victims under rubbles and etc.
- Weather sensor nodes to measure humidity, temperature, wind direction and speed, rainfall, and etc.
- Coordination nodes (B) which have more resources (computing and power) than mentioned nodes.
- PAN Coordinator node (A) which is the destination of all information received from entire network. It has higher processing power and stronger energy resource than the other nodes within the network. This node generates the ultimate expected response of the network through performing complex calculations on data.

In order to reduce energy consumption, sensor nodes are to be set hierarchal and into clusters. Each cluster has a coordinator which as mentioned has more processing power and stronger energy resource than the other nodes in its own cluster. It is also responsible for data aggregating from other sensor nodes and performing inter-cluster calculations on data. After data aggregation received from sensors, coordinator node removes redundant data. Therefore, data transmission and energy consumption get reduced.



A	PAN Coordinator Node
B	Coordinator Node
C	Leaf Node(Sensor Node)
D	Inactive Node(sleep node)

Figure 1: Virtual Network in State of No Traffic in Sensor Network

Despite energy supplies of the cluster head nodes are stronger; still their life is very important because of their vital role in the cluster. If the base station node is far away from cluster head, then sending data directly to the PAN Coordinator will consume a lot of energy via coordinator nodes. Furthermore, due to the high distance, PAN Coordinator node may not be in the frequency range of the sensor node. In this case, it is not possible to send data from the sensor node

directly to the PAN Coordinator node. To solve these problems, a coordinator node should be deployed between sensor node and PAN Coordinator nodes (base station node) so that sending information becomes multi-hop.

Since in the proposed model, network traffic is increasing explosively in time of an event, the node in the last hop toward the base station may become a bottleneck under this traffic load. Also frequent use of this single node can greatly reduces its energy and may lead to dead of that node. Loss of this node leads to the death of entire network. To prevent these problems, the cluster head node in the last hop (second level coordinator node) should be replicated and each node is to be responsible for a part of the network. Fig. 1 shows the structure of the proposed model

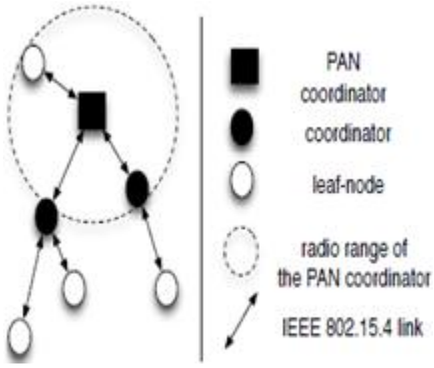


Figure 2: The Structure of the Proposed Model

B. Energy Efficient Routing Algorithm

In design of the routing algorithm for proposed WSN below challenges have to be noticed:

- How to direct packets to a base station in order to minimum energy consumption. (The important challenge)
- Possibility of synchronized sending real-time and none real-time data.

To deal with the challenge of saving energy in the proposed routing, general policy is to reduce energy consumption by turning off unnecessary sensors without affecting on correctness of routing in the entire network. For this purpose, a particular method is to be used in each level. At the lowest level and among sensor nodes in each cluster, a virtual map of the network is drawn. Using global positioning system (embedded within them), sensor nodes map themselves to a geographical region within this virtual network. It should be noted that mapping nodes in a same region in the virtual network have the same routing cost. In this case, it seems that when sensor network traffic is low, one active node in each area seems to be enough [10].

Each zone has just one node in active mode and other nodes are inactive. The active node selection algorithm is following a simple round robin algorithm which results in balanced energy consumption in the whole cluster. Thus, in addition to activeness of the network in low traffic, energy consumption is getting reduced as much as possible. If an active node in each area senses an event, it will send an alarm to neighbors in its area and if necessary, the number of active nodes increases and according to the considered policy. It also cause reduction in leaf node’s (sensor node) traffic and also somehow in redundant data (due to a reduction of data received from nearby areas usually with the same value).

As mentioned in the section 4-A, the policy of reducing energy consumption in the next level and among the coordinator nodes is making routing multi-hop and preventing waste of energy in order to send data over long distances as its result. Finally at the last level, by replication of second level leaf nodes (sensor node) and dividing traffic between the nodes, energy consumption is greatly reduced.

To face the second mentioned challenge for designing proposed sensor algorithm, it should be considered that data have to be directed to the destinations so that ensure deadline for real-time data and provide reliability and performance for none real-time data. To provide these policies in the proposed sensor network some terms considered to note a priority mechanism in sending real-time data in coordinator node (This mechanism is somehow different in the first and second level coordinator node). In firs level coordinator nodes the priority has an inverse relationship with time remaining to reach the deadline of real-time data. In another word, the shorter deadline a packet has the higher priority it contains so it should be sent earlier than other nodes and bandwidth is being allocated to it. But instead of using deadline to determine the priority in the coordinator nodes, an estimated speed is to be used for this determination so that if the packet is sent with that speed, the deadline will be Guaranteed. Equation (1) is used to estimate priority.

$$Priority=\frac{Distance}{Real\ Time} \tag{1}$$

In this level, because the distance between the first and second coordinator node might be different, adding this parameter makes priority determination more accurate. In this case, two packets with same remaining times of deadline and different distance would definitely get more appropriate priority.

An important issue discussed when using a priority algorithm is the probability of starvation for low priority data. In Environment monitoring, none real-time data are considered as low priority data. To avoid starvation in sending data, K percentage of bandwidth (K is a small amount) is assigned to sending this data. These data use bandwidth through a simple queuing mechanism and are directed to the destination. Since, this data typically have to be sent to destination with high reliability, redundancy mechanism will be used for these packets. So that multiple copies (the number depends on the application) generated from those packets and sent from different paths in order to increase the chance of getting to the base station and to reduce packet loss rate as much as possible.

In the weather sensors, to avoid sending redundant data and consequently saving energy in the proposed sensor network, a hard and a soft threshold is being defined in each sensor. If a sensor senses a value equal to or greater than the hard threshold (e.g. high weather temperature), it converts to transmitter mode to send data. After that, just if the variation of sensed parameter is greater than or equal to the soft threshold, sensor will send information to destination again. Therefore, energy consumption is getting reduced and redundant and inefficient data will be prevented from sending.

5. CHALLENGES OF THE PROPOSED WSN

Using hierarchical structure along with clustering in proposed model, producing a coordinated network with independent components, and using a combination of routing algorithms with different approaches that each of them covers other ones' weaknesses, all lead to creation of an appropriate model to be applied in complex situations of disaster management with the following advantages and capabilities:

- Ability to apply different policies and characteristics appropriate with the environment change occurred.
- Network's geographical scalability with minimum cost and with no need to change or the failure of other sectors.
- Localization and prevention of error propagating into other parts of the network.
- Ability to identify and report real-time events before finishing their deadline.
- Ability to send none real-time information with high reliability and low packet loss rate.
- High level of energy efficiency and balance energy consumption in the entire network.

Furthermore, for some reasons such as dynamics and complexity of disaster conditions, following challenges for proposed WSN have been addressed:

- Define policies and tasks related to various parts of the network.
- Relevant complexity of the network associated with diversity in different routing policies.

6. CONCLUSIONS

In this paper the role of Wireless Sensor Networks in environment monitoring was explained and the characteristics and challenges of appropriate WSN for environment monitoring t were mentioned. Wildly used routing algorithms for WSN were categorized and a proper WSN for environment monitoring was proposed. IEEE 802.15.4 is emerging as the standard for Low-Power Wireless Personal Area Networks. We have presented here how we should modify IEEE 802.15.4 to cope with multichip environments

The proposed structure could apply different security and management policies depend on the situations. In addition, a suitable routing algorithm for directing the data packet in the structure was proposed. The proposed routing was heterogeneous and decreased energy consumption. Using the proposed routing algorithm in proposed WSN caused decreasing coast and energy consumption and increasing data transfer reliability and flexibility of network.

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